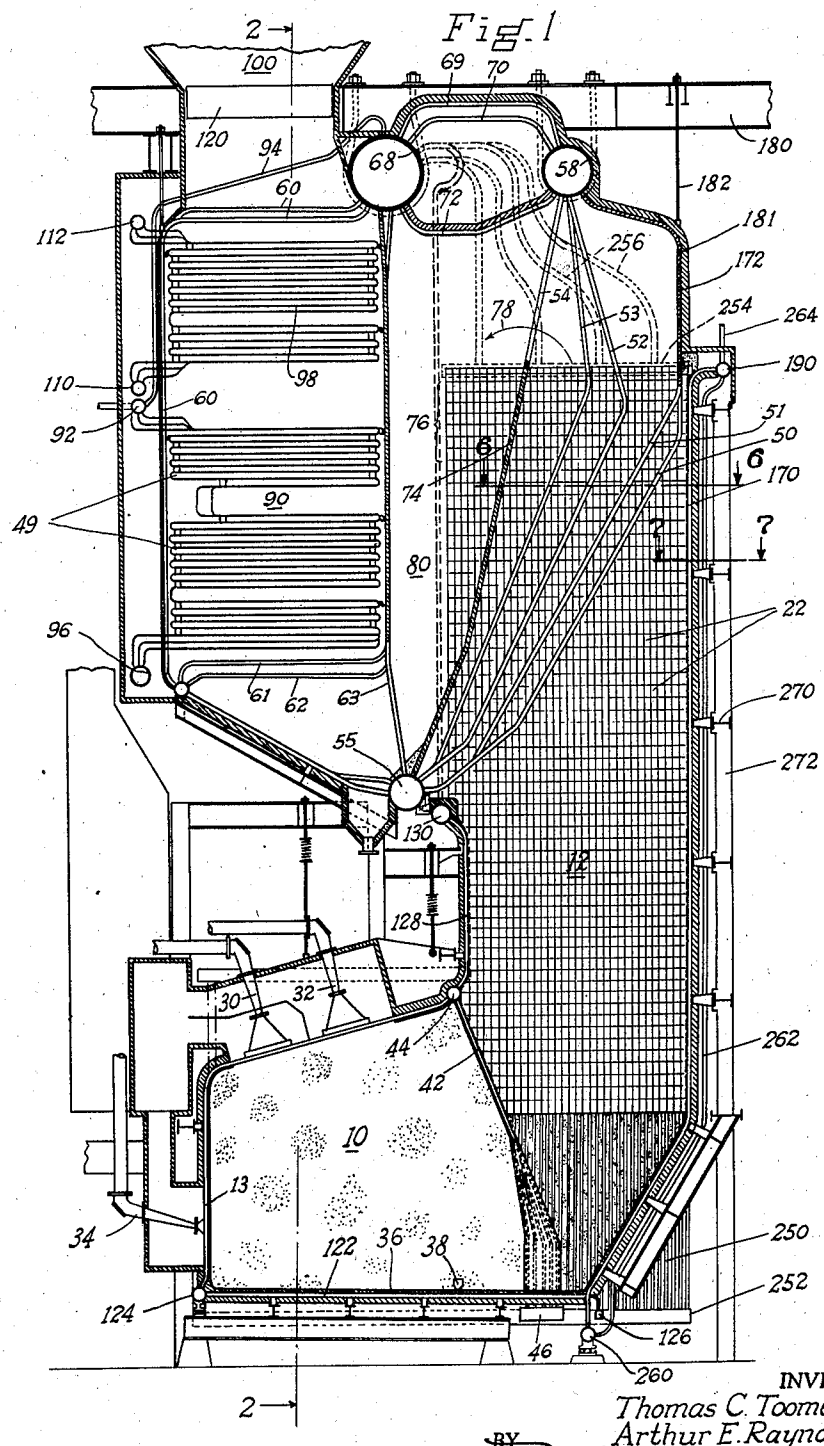
Feb. 18, 1941. T. C. TOOMEY ET AL 2,231,970

FLUID HEAT EXCHANGE APPARATUS

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Fig. 1



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FLUID HEAT EXCHANGE APPARATUS

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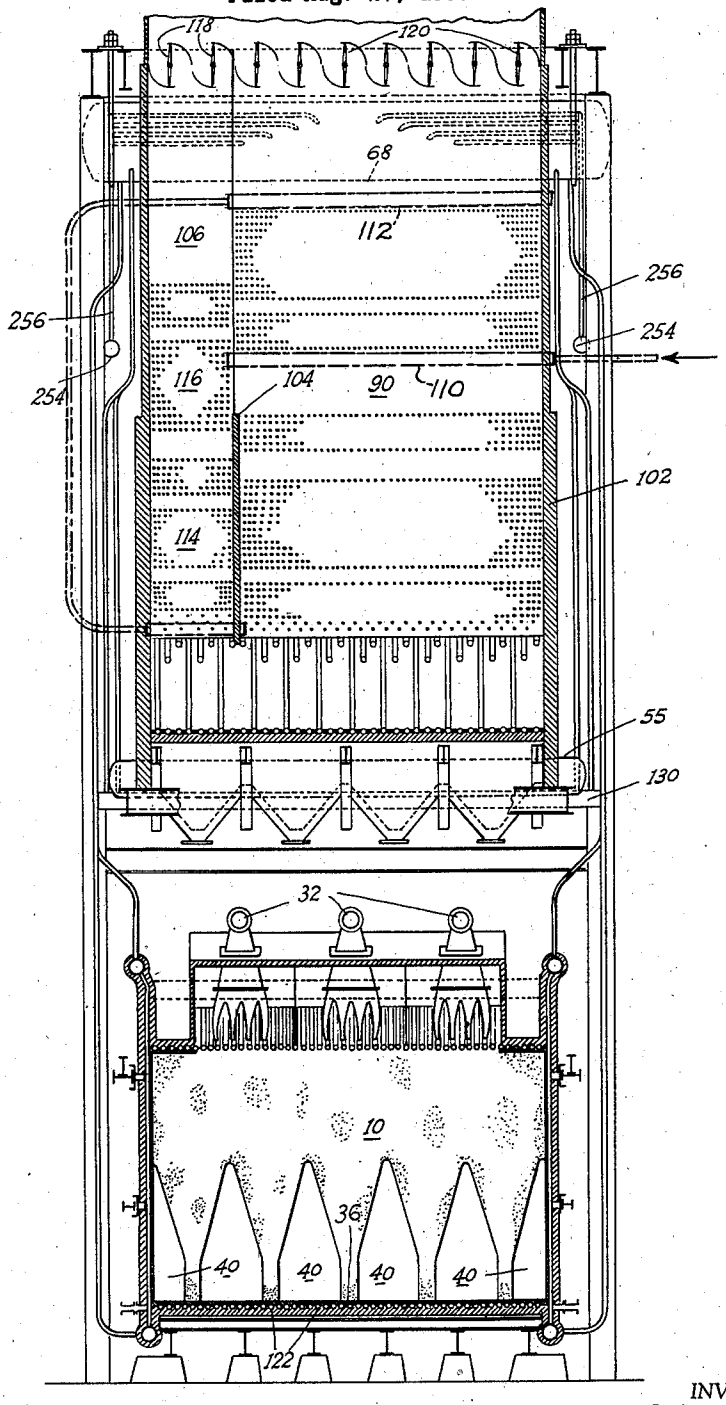


Fig. 2

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FLUID HEAT EXCHANGE APPARATUS

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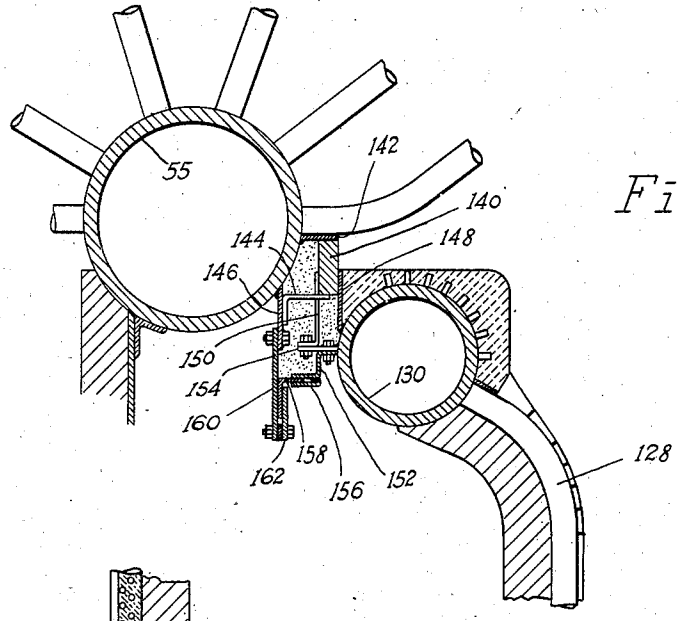


Fig. 3

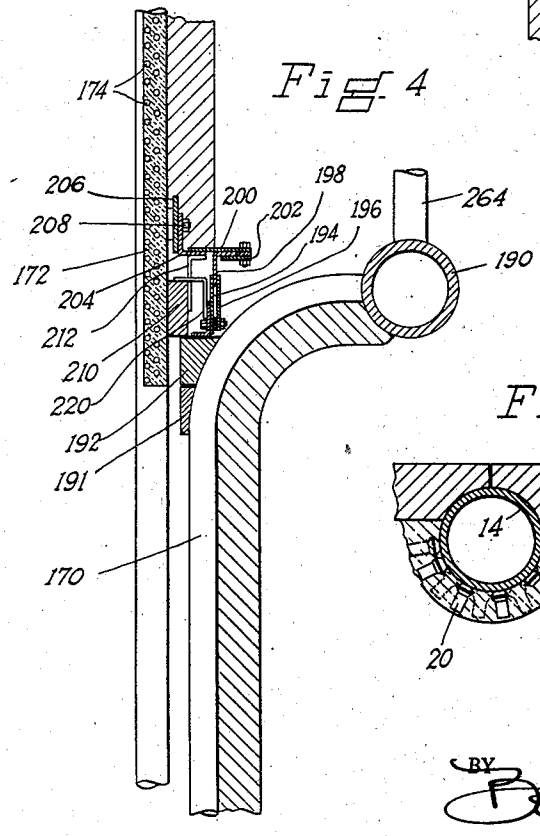
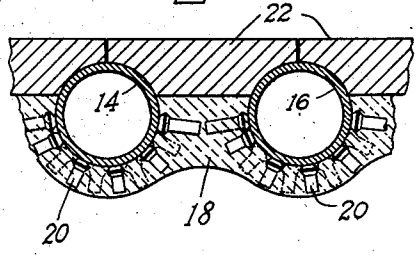


Fig. 4

Fig. 5



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Fig. 6

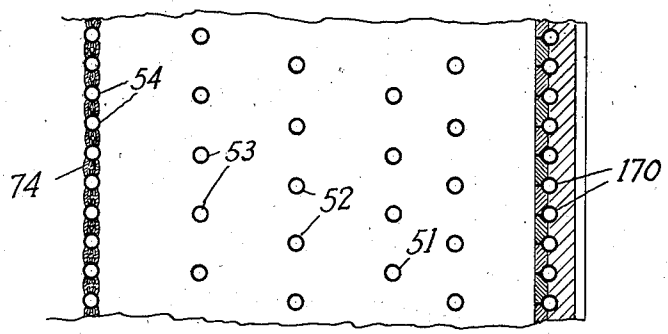


Fig. 7

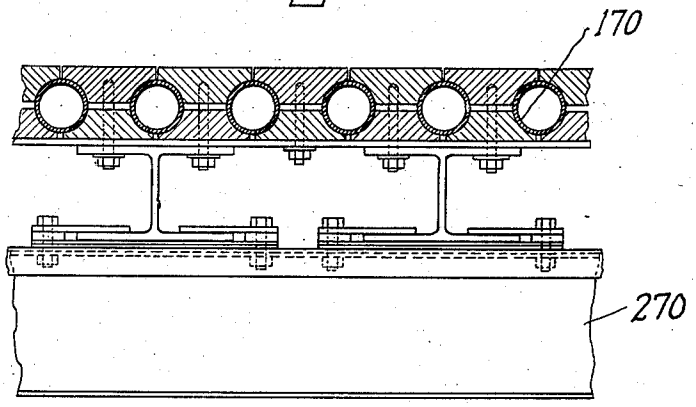
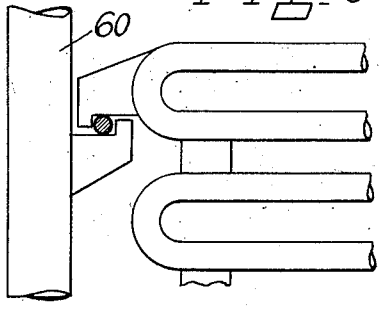


Fig. 8



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UNITED STATES PATENT OFFICE

2,231,970

FLUID HEAT EXCHANGE APPARATUS

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Application August 27, 1937, Serial No. 161,174

6 Claims. (Cl. 122—235)

This invention relates to fluid heat exchange apparatus in which fuel burning conditions and heat exchange conditions are so co-ordinated that the apparatus is capable of high rates of heat liberation and high rates of heat absorption at large temperature differentials between the heat transmitting combustion products and the heat absorbing elements.

It is an object of the invention to economically produce high pressure and high temperature steam for the ultimate production of power. The two stage radiant boiler for producing the steam is characterized by its ability to burn various fuels in suspension while efficiently absorbing heat from the products of combustion and effecting the separation of non-combustible residues of the fuels to such a degree that continuity of operation of the apparatus and the thermal efficiency thereof are maintained over economically advantageous long time periods.

The invention presents a radiant boiler in which the combustion of the fuel and the heat absorption by the working fluid is developed in stages, each stage involving such co-ordination of furnace conditions and heat absorbing surfaces that the ultimate desideratum of slag free furnace gases at the proper temperature at the furnace outlet will be attained. In the operation of the boiler, combustion of the fuel is effected in a high temperature stage wherein, when pulverized coal is used as a fuel, the ash constituents of the coal are fused and caused to coalesce. These constituents simultaneously transfer heat to fluid cooled furnace walls. In the second stage, the products of combustion are subjected to a temperature reduction by the radiant transfer of their heat to wall surfaces of high absorptivity. In this stage not only the gaseous products of combustion, but also the non-gaseous or molten residues are subject to a rapid and considerable reduction in temperature. This action brings the gases within the allowable temperature limits for contact thereby with subsequent superheating surfaces and the molten residues are chilled and congealed to such a degree that deleterious deposits of these residues upon superheater surfaces is eliminated, and discharge of the separated residues from the furnace is facilitated.

It is an object of the invention to maintain such high furnace temperatures in the primary furnace stage that rapid and complete combustion of the fuel is effected. In this stage the ash released during combustion of such an ash-bearing fuel as pulverized coal is maintained in a molten condition as slag in order that it may be continuously or intermittently removed from the furnace while still in a molten condition.

In the secondary furnace stage the object is to present furnace cooling elements of higher rates of heat absorptivity to rapidly receive the radiant heat from the gases and any non-gaseous particles that may be in suspension in the gases, and to so reduce their temperatures, particularly that of the non-gaseous particles in suspension, that when they contact with the convection heating surface beyond the secondary furnace stage, they will be at a temperature below their fusion temperature and will, therefore, be in a dry or such a non-sticky condition that the accumulations of molten slag upon the elements providing the convection heating surface will not occur.

Other objects of the invention will appear in the following description which refers to the accompanying drawings, in which:

Fig. 1 is a vertical section through an illustrative embodiment of the invention.

Fig. 2 is a view in the nature of a vertical section taken at a plane at right angles to the plane of the Fig. 1 section, approximately on the line 2—2 of Fig. 1.

Fig. 3 is a detail view on an enlarged scale showing, in vertical section, the arrangement of the submerged boiler drum with respect to the adjacent water wall header.

Fig. 4 is a vertical section showing in detail the arrangement of the vertically inclined slag screen tubes with reference to the adjacent water wall of the secondary stage of the furnace.

Fig. 5 is a detail view in horizontal section showing the type of refractory faced furnace wall employed in the primary or high temperature furnace stage.

Fig. 6 is a horizontal section on the line 6—6 of Fig. 1, showing the arrangement of tubes at the upper part of the second stage.

Fig. 7 is a detail view taken on the sectional line 7—7 of Fig. 1, showing the construction of the second stage.

Fig. 8 is a detail view showing the manner in which the coils of the convection section are mounted.

In Fig. 1 of the drawings the primary furnace stage is indicated at 10 and the secondary furnace stage generally indicated at 12. In the primary furnace stage high rates of combustion and high temperatures prevail. The walls of this furnace are defined by fluid cooled tubes which are connected into the boiler circulation. Such tubes (see tubes 14 and 16 of Fig. 5 of the drawings) are covered on their furnace sides by ceramic

refractory material 18 which is anchored to the tubes and thermally maintained by the cooling action of the fluid within the tubes by metallic extensions 20 distributed over the furnace faces of the tubes. These extensions are preferably welded to the tubes. The ceramic material is thus bonded to the tubes so that it is maintained thereon as an integral part of the walls even though the furnace face layers of the walls are maintained continuously at high temperatures during the operation of the apparatus.

The walls of the secondary furnace stage 12 present heat absorbing surfaces of high rates of heat absorptivity. These walls may be in the form of a "tube to tube" arrangement of steam generating wall tubes defining the stage boundaries and having their furnace face surfaces bare, or in the form of a "partial stud tube" arrangement in which the wall tubes are spaced apart and the spaces between the adjacent tubes of the wall in the plane of the boundary closed against passage of gases by ceramic refractory material maintained on the tubes and bonded thereto by studs or extensions secured to the tube and projecting therefrom into the inter-tube spaces. Alternatively, the inter-tube spaces in the secondary furnace stage may be closed by imperforate metal extensions projecting from the tubes and arranged in the planes of the boundaries of this stage with the furnace faces of the tubes bare and exposed to the furnace gases. Fig. 1 of the drawings indicates a wall structure in which the tubes of the secondary furnace stage 12 have metallic blocks 22 held in contact with the tubes and forming a gas-tight wall. These blocks not only present heat absorbing surfaces of high rates of heat absorptivity, but they facilitate the removal of ash or molten slag that might be deposited on the walls. They effect this result by providing natural cleavage planes along their smooth wall faces, these planes marking sharp delineations between the furnace faces and any slight slag accumulations which may occur. This results in the slag naturally breaking away from the wall after it has accumulated to such a degree that its weight is greater than that which can normally be sustained by the relatively low adhesion resulting from the smooth natural cleavage planes provided by the surface of the wall.

High rates of combustion prevail in the primary furnace stage and high furnace gas temperatures well above the fusion temperatures of the ash content of pulverized coal are maintained. Burners 30, 32, and 34 are supplied with air preheated to a high temperature and the furnace parts, including the burners, are so arranged that a high degree of turbulence results in a thorough mixing of the preheated air and fuel, which condition is desirable for the rapid and complete combustion of the fuel. These burners are preferably of a type known as "combination burners." This term connotes burners which are capable of independently burning any one of a plurality of fuels, or any combination of those fuels. When pulverized coal is used as a fuel the ash constituent is in molten form because of the high temperatures prevailing in the first furnace stage. This molten ash or slag is to a large extent deposited upon the furnace floor 36 and is maintained thereon in a molten or liquid condition so that its removal is facilitated. It may be removed by permitting it to run out continuously, or it may be tapped intermittently and allowed to flow from the furnace through the slag tap opening 38. In the particular embodiment of the invention illustrated in Fig. 1 of the drawings, the burners are arranged so as to facilitate the flow of this slag toward this slag tap opening.

The molten ash or slag particles in the primary furnace stage 10 are initially in suspension in the furnace gases and not all of these particles are deposited upon the furnace floor. Some of them pass with the gases into the secondary furnace stage 12. The outlet openings 40 through which this movement of the gases takes place are indicated in Fig. 2 of the drawings and they are defined by the refractory covered division wall tubes 42 which connect the upper header 44 with the lower headers 46. Above the outlets 40 these tubes, with their refractory coverings constitute an imperforate division wall which acts as a baffle to deflect the gases downwardly.

As the gases with their suspended slag particles move through the second stage, heat is radiated from these particles and from the gases to the fluid cooled heat absorbing surfaces provided by the wall tubes and the metallic furnace wall blocks. This heat transfer results in such decreases in the temperature of the gases and the non-gaseous particles in suspension that the particles are in a dry solid form before they contact with the heating surfaces of tubes beyond the second stage. This desirable action is enhanced by action resulting from the difference between solid and gaseous radiation. The greater radiation from the solid particles results in these particles attaining a somewhat lower temperature than the surrounding gases. Thus fouling of the spaced tubes of convection heating surfaces beyond the second stage, and particularly the tubes of the superheater 49 is prevented.

The furnace gases and their suspended non-gaseous particles beyond the second stage are further cooled by contact with and the radiant transfer of heat to the widely spaced slag screen tubes 50–54, inclusive. These tubes are connected into the boiler circulation by reason of their communication at their lower ends with the submerged drum 55 and at their upper ends with the front drum 58. During the operation of the apparatus a mixture of steam and water flows upwardly through these tubes to the drum 58, other boiler circulation taking place through the circulators 60–63, inclusive, the steam and water drum 68, the steam circulators 69 and 70, and the water circulators 72.

The tubes 54 are preferably in wall alignment and the spaces between these tubes are closed by refractory material which forms the baffle 74 extending upwardly from the drum 55 to a position near the top of the secondary stage side wall 76. The furnace gases pass around the top of this baffle as indicated by the arrow 78, move downwardly through the gas pass 80 and pass between the screens formed by the lower parts of the circulators 61, 62, and 63 to the spaced tubes of the superheater 49. All of these tubes contacting with the furnace gases leaving the second stage are widely spaced so that they do not excessively cool the furnace gases before they reach the superheater. When high superheat is provided the high temperature gases thus contacting with the superheater elements eliminate the necessity of providing an excessive amount of superheating surface to attain the superheat desired.

The superheater 49 consists of the closely spaced tube sections of return bend coils extending across the upward flow of gases in the

gas pass 90 and receiving saturated steam from an inlet header 92 connected by the tubes 94 with the steam space of the drum 68. The superheater preferably operates upon the counter-flow principle with the steam flowing downwardly to the superheater outlet header 96 while the gases flow upwardly in the gas pass 90 across the tube sections of the economizer 98 and to the flue 100.

The tube sections of the superheater coils and the economizer coils may be maintained in their properly spaced arrangement by supports welded to the upright sections of the circulators 60–63, inclusive, such supports permitting the coils to be readily removed and replaced. Furthermore, the cooling action of the fluid in the circulators upon the metallic supports prevents damage to the supports by the high temperature furnace gases.

The gas pass 90 for the superheater is defined on one side by the wall 102 and upon the opposite side by a partition 104 which separates the bypass 106 from the gas pass 90. Feed water enters the economizer inlet header 110; flows through the return bend tubes of the economizer section 98 to the header 112; and then flows downwardly to a position near the gas inlet of the bypass 106 from which position it is conducted through headers and return bend tubes through successive parallel flow economizer sections 114 and 116. The flow of gases over these two economizer sections through the bypass 106 is regulated by the bypass dampers 118 which in combination with the dampers 120 at the outlet of the gas pass 90 serve to maintain uniform steam temperatures over a wide range of gas flow.

The front wall and roof of the combustion chamber 10 of the primary furnace stage are defined by the tubes 13 which extend upwardly past the burners 30 and 32 and connect at their upper ends to the header 44. These tubes are covered on their furnace sides with ceramic refractory material as indicated in Fig. 5. Similar arrangements of tubes and refractory coverings constitute the side walls of the primary stage and the floor is defined by the tubes 122 communicating at their forward ends with the header 124, and at their lower ends with the header 126 which may be suitably connected into the boiler circulation. The side walls may be sustained by bottom supports such as are shown beneath the header 124.

The wall tubes 128, connecting the headers 44 and 130 act as risers to conduct the mixture of steam and water from the wall tubes of the combustion chamber 10 upwardly and this mixture passes directly from the header 130 through suitable uptake connections to the steam and water drum 68.

The submerged drum 55 is preferably supported by the tubes 50–54 inclusive, and the tubes 63, and it is thus susceptible of some downward and lateral movement when the boiler is brought up to operative temperatures. The header 130 is not supported by the same arrangement of tubes and hence is not subjected to the same movements. Therefore, a gas seal is provided between the header 130 and the drum 55. This seal is shown in detail in Fig. 3 of the drawings. It consists of refractory blocks 140 held in position vertically with respect to the drum 55 by a plate 142 and lugs 144. The plate is preferably welded to the drum 55 as shown and the lugs 144 are secured to an upright plate 146, which, in turn, is welded to the drum. The blocks 140 are freely movable horizontally in the guideway provided between the plate 142 and the lugs 144 and this guideway maintains the blocks 140 in sealing relationship to the drum 55. An intersecting vertical guideway for the blocks 140 is provided between the upright plate 148 and the lugs 150, the latter being interspersed relative to the lugs 144.

The plate 148 is preferably welded to the header 130 and the lugs 150 are fixed to this header through the intermediacy of the horizontally extending plate 154. Spaced from the lower flange of the Z-bar 152 and rigidly secured thereto is a guide plate 156 which co-operates with the lower flange to provide a horizontal guideway for the horizontal flange of the floating angle 158. The vertical flange of this angle is free to slide in a guideway formed by the depending plate 160 and its companion plate 162. The latter elements are rigid with respect to the drum 55. The spaces below and laterally of the sealing blocks 140 and above the floating angle 158 may be filled with some suitable insulating material such as asbestos.

The tubes 50 and 51 are widely spaced at positions wherein they are traversed by the furnace gases, but at positions near the wall tubes 170 these tubes are brought into a single upright wall alignment. From these positions upwardly the furnace wall is completed by ceramic refractory material 172 closing the spaces between the upper parts of the tubes 50 and 51 and anchored and thermally bonded to the tubes by metallic studs 174. This partial "stud tube" wall 181 is suspended from the beam 180 of the boiler setting framework by the hangers 182. The roof shown as an upward continuation of the wall 181 is also supported by the hangers 182.

Provision is made for permitting relative movement between the boiler wall 181 and the second stage furnace wall defined by the wall tubes 170. The latter tubes, as indicated in Fig. 4 of the drawings, are curved outwardly at their upper ends and are connected to the header 190. At the positions wherein these tubes curve away from their vertical positions the spaces between the tubes are closed by metallic blocks 191 and 192, the latter affording supports for the plates 194 and 196 which form a vertical guideway for the vertical flange of the floating angle 198. The horizontal flange of this floating angle is free to move in a guideway presented by the spaced plates 200 and 202 which are fixed with reference to the tubes 50 and 51 by the angle 204, the plate 206, and the studs 208. Sealing blocks 210 of refractory material are held against the partial stud tube boiler wall by brackets 212 which co-operate with that wall to form a vertical guideway for the blocks. The lower surfaces of these blocks are held in contact with the upper surfaces of the blocks 192 by the brackets 220 which are fixed with reference to the other guide members 194 and 196. A horizontal guideway for the blocks 210 is thus formed and the spaces between these blocks and the other seal forming elements may be filled by a compressible heat insulating material.

The side walls 76 of the second furnace stage include the upright wall tubes 250 communicating at their lower ends with the headers 252 and at their upper ends with the headers 254. The latter are connected with the steam space of the drum 68 by risers 256. The parts of these tubes above the level of the gas outlets 40 have their

spaces closed by the metallic wall blocks 22 but in the higher temperature turning zone of the furnace gases adjacent the outlets 40 the walls of the second stage are preferably provided with a stud tube and ceramic refractory construction. The downwardly inclined lower parts of the wall tubes 170 are provided with a protective tube covering. These tubes communicate at their lower ends with a header 260 which may be connected with the upper header 190 by the recirculators 262. Appropriate risers 264 connect the upper header 190 with the steam and water space of the drum 68.

The division wall 42 between the primary stage 10 and secondary stage 12 consists of spaced tubes with a "full stud tube" construction over their higher temperature sides presented toward the primary stage. This construction presents a high temperature ceramic refractory furnace face to the combustion chamber 10 of the first stage and is similar to the construction for the remaining walls of this combustion chamber. The ceramic refractory material constituting the lining for this chamber is installed over the studs and the tubes in a moldable condition and is tamped or otherwise pressed into place.

Upon the opposite side of the division wall 42, or on the side of this wall presented toward the second stage 12, metallic furnace wall blocks similar to the blocks 22 of the remaining walls of the second stage may be secured to the division wall tubes. This side of the division wall may be of other construction such as a partial stud tube construction. The upper portions of these tubes are preferably in single row alignment, but just above the gas outlets 40 these tubes are bent out of this wall alignment and below these points the tubes are arranged to define the side walls of the outlets 40. The lower parts of these tubes are preferably provided with the "full stud tube" construction. These parts, constituting the walls of the gas outlets 40 act as a slag screen, causing gas mixing to promote combustion of any combustibles that may remain unburned in the gases at this point, and furthermore effecting some separation of slag particles by adhesion thereto.

The wall tubes 170 forming the rear wall of the second stage 12 are held in wall alignment by guides which include the beams 270. These beams may be fixed to the columns 272 and have a slidable relation to the wall tubes 170 in order that the latter may be held in wall forming alignment while still free to move because of expansion or contraction. It is also clearly indicated in Fig. 1 of the drawings that the rear wall of the second furnace stage 12 is inclined downwardly toward the floor 36 of the primary furnace stage 10, and means are shown for supporting this lower part of the wall in this position.

The illustrative embodiment of the invention indicated in the drawings involves an arrangement of the different stages and the other components whereby economical power generation may be effected over a wide range of gas flow. This results from the high rates of combustion and high furnace temperatures which may be attained in the primary furnace stage. Considering the range of operation there is always some range below which it is difficult to maintain the slag at the bottom of the furnace in a molten condition so that it may be effectively removed, and the higher the temperature of the primary stage at a normal or maximum capacity the higher the temperature will be at lower capacities. The relatively small volume of the primary stage also promotes this capability of the illustrative embodiment to be effective for exceedingly low capacities as well as at high capacities. One of the characteristics of the illustrative embodiment which permits such range of operation is the arrangement of the convection surfaces in such a position that they cannot "see" the primary stage of the furnace in which the high rates of combustion and high temperatures prevail. This promotes long continued effectiveness of the convection surfaces when the operation of the unit is considered from the standpoint of slag accumulations on such surfaces, and additionally, further accelerates the rapid decrease in temperature of the gases in the secondary stage.

The above indicated arrangement of the elements wherein the economizer and the superheater are positioned laterally of the top of the secondary stage and above the high temperature primary stage also involves an effective utilization of head room and the total available space for the whole installation. This arrangement also involves an economy of cost as to the supporting framework of the boiler setting. Some of the parts of the setting framework utilized in conjunction with the erection and support of the primary stage may also be utilized in connection with the erection and support of the economizer and superheater. These advantages would not be present if the convection section consisting of the economizer and superheater were located oppositely of the second stage, with respect to the primary stage.

Although the invention has been described with reference to the particular embodiments which are shown in the accompanying drawings, it is to be appreciated that it is not limited to all of the details and arrangements of elements shown in those drawings. Various components of the steam generating unit illustrated in Fig. 1 of the drawings may be utilized in combinations of the other components which may vary from those illustrated, within the scope of the sub-joined claims.

We claim:

1. In a steam boiler of the bent tube type, an upper drum, a lower drum, steam generating tubes connecting said drums and having vertically inclined parts extending across the path of furnace gases, the upper parts of said tubes being bent to extend upwardly in wall forming alignment, refractory means closing the spaces between said upper parts to form an upright boiler setting wall, means completing the boiler circulation through said drums and tubes, a furnace including a water wall adjacent the lower portion of said setting wall and substantially parallel thereto, and a combined expansion joint and gas seal structure between said walls for maintaining a gas tight closure while permitting relative movements of said walls due to exposure to a wide range of furnace gas temperatures and due to the provision of separate supports for the walls.

2. In a vapor generator, inclined vapor generating tubes having parts extending across the path of furnace gases, the upper parts of the tubes defining a gas confining wall, refractory means associated with said upper parts to close the spaces between the tubes, a second wall extending downwardly from the first wall and including spaced wall cooling tubes, refractory means closing the spaces between the latter tubes, means for separately supporting said walls whereby the heating of said walls causes relative movements

of said walls near the top of the second wall, said last named means maintaining the top of the second wall in operative position adjacent the bottom of the first wall, and a combined expansion joint and gas seal structure between said walls for maintaining a gas tight closure while permitting said relative movements of the walls.

3. In a water tube steam boiler, an upper fluid chamber, a lower fluid chamber, steam generating slag screen tubes connecting said chambers and having vertically inclined parts extending in widely spaced relationship across the path of furnace gases, the upper parts of said tubes being bent to extend upwardly in wall forming alignment, refractory means closing the spaces between said upper parts to form an upright boiler setting wall, means completing the boiler circulation through said fluid chambers and tubes, a furnace including a water wall adjacent the lower portion of said setting wall and substantially parallel thereto, and a combined expansion joint and gas seal structure between said walls for maintaining a gas tight closure while permitting relative movements of said walls due to exposure to a wide range of furnace gas temperatures and due to the provision of separate supports for the walls.

4. In a steam boiler, means forming a lower water chamber, means forming an upper water chamber, inclined steam generating tubes directly connecting said chambers, spaced furnace wall tubes arranged as a part of a furnace wall with its upper end adjacent the lower water chamber, sealing means permitting relative movements of said wall and the lower chamber while preventing the escape of furnace gases therebetween, said means including a floating angle, a similar furnace wall adjacent the upper ends of some of said steam generating tubes, similar sealing means between the latter tubes and the last named furnace wall, and means for burning fuel in the furnace.

5. In a water tube steam boiler, an upper fluid chamber, a lower fluid chamber, steam generating slag screen tubes connecting said chambers and having inclined parts extending in widely spaced relationship across the path of furnace gases, other parts of said tubes being bent to extend upwardly in wall defining alignment, means co-operating with said other parts to form an upright boiler setting wall, means completing the boiler circulation through said fluid chambers and tubes, a furnace including a water wall adjacent the lower portion of said setting wall and substantially parallel thereto, and a combined expansion joint and gas seal structure between said walls for maintaining a gas-tight closure while permitting relative movements of said walls due to exposure to a wide range of furnace gas temperatures and due to the provision of separate supports for the walls.

6. In fluid heat exchange apparatus including a furnace; two adjacent fluid cooled structures exposed to the heat of furnace gases; separate supports for said structures; and a gas tight triple seal between said structures; said seal including an inner component including a refractory member, means maintaining the refractory member in contiguous relationship to each of said structures, an outer component including a body movable with respect to at least one of said structures, and loose heat insulation material between said body and said refractory member, said inner and outer components being maintained in their operative positions independently of said insulation material.

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